Soil and Plant Analytical Services for Tree Nurseries[1]

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Abstract.--A cooperative program between the USDA Forest Service State and Private Forestry and the State University of New York provides a service of standardized soil and plant analysis and data interpretation oriented toward the needs of nurserymen. The program provides nurseries with information to aid in making soil management decisions, and also serves as a data bank for an increasingly broad base of soil and environment conditions, seedling species and management cultural treatments.

There are private and public laboratories presently providing soil and plant analysis services, but unfortunately these labs are mostly agriculturally, public health, and/or food industry oriented, and are usually not in a position to supply meaningful interpretations of soil and/or plant analysis data to tree nurserymen. Nurserymen have sought guidance with interpretive data from such labs, and in some cases have over the years learned how to relate the lab data to the condition of their stock. More often than not, however, the data lead to frustration and nurserymen fall back on old rule of thumb fertilization practices or, the "We'll put it on whether we need it or not!" routine. This is especially frustrating to new nurserymen who have very short thumbs on which to rule. With increasing fertilizer costs and the emphasis on more efficient production, nurserymen have expressed a need for reliable diagnostic tests on which to base their soil management programs.

Supplying this need was one of the objectives that the U. S. Forest Service, Northeast Area, State and Private Forestry had in mind, when they and the State University of New York College of Environmental Science and Forestry entered into a cooperative agreement in 1974 for the benefit of Northeast Area nurseries. The College's Forest Soils Laboratories undertook that part of the overall effort involving annual monitoring of soil fertility and seedling quality as a means of improving nursery soil management. In addition, other closely related activities were conducted, i.e. stocking density and seedbed thinning evaluations. There is no question that seedbed density has an overwhelming impact on the quality of seedlings produced by nurseries. Without satisfactory seedbed density control, i.e. about 20 seedlings per square foot of seedbed area, the value of intensive soil management on the quality of seedlings produced may be masked.

Also, analyses have been performed on various organic materials used in nurseries as soil additives and conditioners. We have encouraged nurseries to make use of society waste materials, i.e. manure, wood chips, sludge, etc. as a source of organic matter and supplemental nutrients. However, we strongly recommend that their use in nurseries be closely monitored to minimize hazards of marked changes in soil reaction or producing heavy metal phytotoxicity problems. The use of such waste materials, where available, may provide nurseries with alternatives to costly commercial inorganic fertilizers to help improve the productivity of their soil, and may help solve a community's waste disposal problem. Frequent analyses of these waste materials must be made to avoid overloading the soil and resulting in a negative impact

[1]Paper presented at the Intermountain Nurseryman's Association Meeting, Aspen, Colorado, August 13-16, 1979.

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on the quality of the stock being produced and on the environment around the nursery area.

Some of the nurseries were able to adjust their soil management programs as per our recommendations and the quality of their stock showed marked improvement. For example, the stock at one state nursery showed marked improvement after the nurserymen reduced their sowing rate (which was purposely high to balance mortality from frost heaving), incorporated organic matter into their very sandy textured soil to increase the cation exchange capacity and moisture holding ability, and added fertilizer where our analytical data pointed out suspected deficiency levels.

At another nursery, limited fertilization had been done in recent years due to budget constraints and the high cost of commercial inorganic fertilizers. But analyses of soil and seedlings showed that various nutrient levels ranged from fair to luxurious. Organic matter and phosphorus levels in the soil were very high due to routine addition of composted hen manure and green manuring between rotations. We recommended that no phosphorus fertilizer be added to the soil until future soil nutrient monitoring showed it was needed. At this nursery, stock quality appeared to be very good for conifer species and was salable as 2-0 stock, becoming too large if left in the seedbed for a third year.

In addition to the annual sampling of soil and seedlings, a study was established at two state nurseries to evaluate in detail seedling growth and development over time. Separate samples of soil and seedlings of several conifer species common to both nurseries were taken at weekly intervals over two growing seasons to determine seedling development and nutrient uptake from seed germination to salable stock under normal nursery conditions. Soil chemical analysis and seedling morphological and chemical analyses are being related to degree day summations at each nursery. This is being done to correlate the growth and development patterns and nutrient uptake rates of seedlings with an important climatic component, temperature, to evaluate the timing of fertilizer topdressings rather than rely on fixed calendar dates regardless of climatic conditions of any growing season.

At the end of the initial cooperative agreement it was concluded that:

1) a long term available service of the *type* we were providing would be useful to public and private tree nurseries;
2) a regular program of soil and seedling analysis should become part of each nursery's operating procedure; and
3) the soil and plant analysis work done at Syracuse be continued.

Continuation of this service to nurseries should provide data and recommendation inputs to help nurserymen in their soil management decision-making processes toward improving their production of high quality outplanting stock in an efficient manner and in a minimum rotation period. Also, the service should assemble additional baseline data to strengthen fertilizer recommendations. A primary consideration is to provide comparable and consistent data over time. Therefore, the Forest Soils Laboratories at Syracuse continue to cooperate with the U.S. Forest Service, State and Private Forestry, in the Northeast Area, Western Area, and Southern Area, and make its analytical services available to all state, federal and private tree nurseries.

Both soil and plant analyses are useful tools if properly used: soil analysis attempts a direct measure of soil nutrient supply; plant analysis is a direct measure of nutrient uptake and an indirect measure of soil nutrient supply. A regular program of monitoring nutrient supply and uptake and recommending soil amendments when needed to keep nutrient levels at near optimal levels, provides an important aspect of stock quality control. Such control employed prior to and during seedling growth and development will result in more efficient use of seedbed space and should help minimize culling at seedling harvest time.

In order to meaningfully interpret soil and/or plant analysis data it must be compared with sound baseline data generated from past sampling and analyses, or with available data assembled from the literature. Fertilizer recommendations must be based on such comparisons. Understand that it is extremely important that the methodologies of sampling and analyses used in a current analytical program and those used to generate the baseline data, identifying expected deficiency levels upon which interpretation of the current analytical results is based, must be the same. Variations from standardized techniques in such things as time of sampling, handling samples in preparation for analyses, relatively minor-appearing modifications in sample preparation and analytical procedures will result in data that cannot be validly compared with known baseline values, no matter how carefully the data were produced.

Since we do not yet feel in our six years of nursery soil and seedling analyses that we have compiled sufficient raw data upon which to set standards of near-optimal levels for a large variety of nursery tree crops, we rely on the compilations of one who has - Dr. S. A.

Wilde. We use the recommendations of Wilde et al. (1972)3 as a guideline and use methods of sampling and analysis that are, we believe, safely comparable with those used by Dr. Wilde. His values are based on long-term compilations from many years of nursery soil analysis experience. For our recommendations we approximate Dr. Wilde's intermediate sail fertility ratings for conifers and high ratings for hardwoods as minimal . The following is a list of threshold values we presently employ at Syracuse (using our analytical methods):

If the cation exchange capacity (cec) expressed in me/100g is less than 8.0 for beds with conifer seedlings or less than 11.0 for hardwoods-ornamentals, it is low and needs attention.

If the soil organic matter level (Loss-on-Ignition method for eastern nurseries or Walkley-Black method for western nurseries) is much below 4.0 to 5.0%, it is probably low and needs attention.

To correct low cec levels where necessary, add massive amounts of organic matter, i.e. one to three inch depth, between rotations of seedlings and rototill it into the soil. Care is needed to add organic matter with a relatively narrow *C/N* ratio or supplement organic matter with some *N* fertilizer to minimize developing chlorosis in seedlings or cover crops.

If total *N* is less than 0.15% for beds with conifer seedlings or less than 0.20% for hardwoods-ornamentals, it is low and needs attention. Correcting for low cec and soil organic matter by addition of massive amounts of organic matter will probably correct total N levels.

If electrical conductivity expressed in millimhos per cm is greater than about 2.0 to 3.0, it may be too high and detrimental to seedlings. This measure of total salt concentration may be a problem for western nurseries and needs attention.

If soil reaction (pH) is less than pH 5.5 for conifers or less than pH 6.0 for hardwoods-ornamentals, lime is probably needed to raise pH above these values (approximately one ton of limestone per acre will increase pH values about 0.5 pH units, depending upon soil texture, organic matter, and initial soil acidity level). If reaction is greater than pH 6.5 for conifers or greater than pH 7.0 for hardwoods-ornamentals, sulfur is probably needed to lower pH below these values (approximately 500 pounds of powdered elemental sulfur per acre will decrease pH values about 0.5 pH units, depending upon soil texture, organic matter, and initial soil alkalinity level).

If soil P is less than 100ppm for beds with conifer seedlings or less than 150 ppm for hardwoods-ornamentals, it is low and needs attention. This P recommendation is about four-fold greater than Dr. Wilde's recommendation, and is based on five years of working with northeastern species; certainly it needs to be further evaluated, but is our best current judgment.

If soil K is less than 100ppm for beds with conifer seedlings or less than 150 ppm for hardwood-ornamentals, it is low and needs attention.

If soil Ca is less than 500ppm for beds with conifer seedlings or less than 1000ppm for hardwoods-ornamentals, it is low and needs attention.

If soil Mg is less than 150ppm for beds with conifer seedlings or less than 250ppm for hardwoods-ornamentals, it is low and needs attention.

Certainly the above values are tentative and subject to modification as we learn more about various species and responses to cultural treatments. It should be clear that we are not employing any revolutionary techniques of nursery soil and seedling sampling and analysis. We are purposely employing detailed methods because of their reliability and repeatability. The reliability of standardized techniques of sampling and analysis is crucial to the success of the service that we are providing. We want the service made available to as many nurseries as possible and oriented toward nursery crops. Recommendations will be based on the needs of nursery crops as best as we currently understand them. Also, data generated by the service should be comparable over time so that patterns of nutrient supply and uptake in individual nurseries can be documented over a period of years. A complete computer center is available at the College and all generated data is stored and available to us for statistical analyses. As long as our methodology remains unchanged, we will continue to add nursery soil and seedling analysis data to this file. Sufficient data

[3]Wilde, S. A., G. K. Voigt, and J. C. Iyer. 1972. Soil and plant analysis for tree culture. Oxford and IBH Publ. Co., New Delhi India (Distributed in North America by Dr. S. A. Wilde, Madison, Wisconsin) 209p.

collected over time will lead to the establishment of refined baseline data levels.

Ideally we seek to determine the near optimal soil and seedling values for each nursery that will result in optimum stock production and quality for each tree species grown. The development of such nursery and species-specific baseline values can be documented only after routine, standardized soil and seedling analyses data are collected over a long time period.

Relating soil and seedling chemical analyses values to stock quality requires that seedlings be analyzed morphologically as well as for their chemical composition. Sampling of intact seedlings provides weights and measurements foraquality index formula. We use a quality index:

$$\text{Quality Index} = \frac{\text{Total seedling dry weight (g)}}{\frac{\text{Height (cm)}}{\text{Diameter (mm)}} + \frac{\text{Shoot weight (g)}}{\text{Root weight (g)}}}$$

which assumes that the larger the seedling, within limits, the better as long as it is a balanced seedling; thus the total weight is balanced by the height:diameter quotient and the shoot:root ratio.

The final measure of real seedling quality is the ability of the seedling to survive and perform well after outplanting. However, seedlings of the highest potential quality may encounter various adverse conditions between lifting and outplanting which will diminish their success in the field. Overheating or desiccation in transport, or careless planting may occur beyond the nursery gate and much or all of the nurseryman's efforts to provide real quality seedlings may be undone. These potential problems deserve the close attention of field foresters. Production, lifting, shipping, outplanting and establishment of high quality seedlings requires close cooperation between nursery and field levels of the forestation process. The seedlings' ability to survive and perform well in the field is difficult to predict. We must learn to relate real seedling quality to morphological characteristics that are quantifiable, yet based on firm physiological grounds, and related to the seedling nutrient element status. The file of seedling quality index data that we are building along with corresponding seedling chemical values, soil chemical values, and cultural treatment records, becomes more valuable as it increases in number and species over the years. The file will be a major asset in increasing the level of accuracy to which we are able to identify critically low or deficient levels of nutrients from adequate and near-optima] levels for varying species, age classes, and nurseries.

We at Syracuse are just beginning to learn about western nurseries. The 1978 sampling season was the first in the program to take us into the land of saline soil and tumbleweed competition. The analyses of these western nursery samples present some problems in the lab that were not encountered with eastern nursery soils. For example, our method of determining the organic matter level of soil was inappropriate for calcareous soils so we used a wetoxidation method for the western calcareous soils that provides truer organic matter estimates. Also we have altered our cec analytical methods for high calcareous soils according to Richards (1954)4. Thus, we are learning about western nurseries and analytical problems associated with high reaction soils, and the needs of species grown on them. It is our hope to be able to supply western nurseries with the same level of reliable and comparable analytical data and interpretation as we have provided eastern nurseries. We will continue to make adjustments in our operation as our western nursery experience dictates.

Each participant in this meeting has been given a handout containing portions of the soil and seedling data distributed to all nurseries participating in our service in 1978 plus cover letters of the soil and plant analysis data, and a statement on Nursery Soil and Seedling Sampling and an order form for participating in our service. There are five different sections to the computer printouts: three of these present examples of soils data; and two present examples of seedling data.

Section 1 contains texture data of the top 6-inch soil depth. The heading at the top of the sheet reads:

NURSERY SOIL SAMPLES COLLECTED FALL 1978 SAND SILT CLAY NAME CODE DESCRIPTION

Each line represents one sample, identified under the heading of CODE and DESCRIPTION (These are explained in the soil cover letter which accompanies each data packet. The first sample of the sheet, 78 CO FC, is from Fort Collins, Colorado. A-2-NORTH 1-0 PONDEROSA PINE locates the sample in the nursery and notes the age and species present at time of sampling. The numbers under the SAND, SILT, CLAY columns are percentage of each and SALO under the heading NAME is the soil textural name, sandy loam, for that soil sample. So according to the first line in the first section of the soils data: a soil sample from area

[4]Richards, L. A. Editor. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Hdbk. 60. U.S. Govt. Print. Office, Wash., D. C. 160p.

A-2-North of the Fort Collins, Colorado State Nursery, is a sandy loam of 71.3% sand, 15.0% silt, and 13.7% clay.

Section 2 contains soil reaction, organic matter, and chemical data of the top 6-inch soil depth. The heading at the top of the sheet reads:

NURSERY SOIL SAMPLES COLLECTED FALL 1978
PH ORGANIC MATTER N P K CA MG CODE DESCRIPTION LOT
WB PERCENT**PPM

Again, each line represents one sample identified under the columns CODE and DESCRIPTION. From left to right are values for the identified soil samples: pH, % organic matter by loss of ignition (LOT) and/or the WalkleyBlack wet oxidation (WB), % total nitrogen (N), and parts per million (PPM) phosphorus (P), potassium (K), calcium (CA), and magnesium (MG). At the top of the page immediately following the one just described, the chemical analysis data for the same sample 78 CO FC A-2-NORTH 1-0 PONDEROSA PINE continues under the heading:

NURSERY SOIL SAMPLES COLLECTED FALL 1978 MN
NA FE ZN AL CEC EC CODE DESCRIPTION ----
PPM ---------- ME/100G

From left to right are values for the identified soil samples: parts per million (PPM) manganese (MN), sodium (NA), iron (FE), zinc (ZN), aluminum (AL), cation exchange capacity (CEC) expressed in milliequivalents per 100 grams (ME/1000), and electrical conductivity (EC) expressed in millimhos per centimeter which is a measure of salt concentration. So, according to the first line in the second section of soils data: soil sample A-2-North from Fort Collins, Colorado State Nursery has a pH of 6.7, organic matter of 3.32% and 2.02% by the loss of ignition and wet oxidation methods, respectively, 0.086% total nitrogen, 130.4 ppm phosphorus, 242.0 ppm potassium, 1555.1 ppm calcium, 178.1 ppm magnesium, 0.56 ppm manganese 18.21 ppm sodium, 0.19 ppm iron, 0.56 ppm zinc, 1.14 ppm aluminum, a cation exchange capacity in excess of 20.0 milliequivalents per 100 grams, and electrical conductivity of 0.5 millimhos per centimeter.

Section 3 contains recommended rates of N, P, K, Ca, Mg fertilizer needs. The heading at the top of the sheet reads:

RECOMMENDATIONS FOR NURSERY SOIL SAMPLES N
P205 K20 CA MG PH CEC CODE
**POUNDS PER ACRE

COLLECTED FALL 1978
DESCRIPTION

For each sample, identified under CODE and DESCRIPTION on the right side of the sheet, there are two lines of data, one labeled CONIFER and one labeled HARDWOOD on the left side of the sheet. This is to provide information for preparing seedbeds for either conifer crops or the more demanding hardwood-shrub species. Nitrogen (N) is expressed as either LOW or OK, phosphorus (P) is expressed in pounds per acre P_2O_5 needed to bring the soil up to guideline or baseline levels, potassium (K) is expressed as pounds per acre K20 needed to bring the soil up to guideline or baseline levels, calcium (CA) and magnesium (MG) are expressed in pounds per acre needed to bring the soil up to guideline or baseline levels, pH adjustments are expressed as either pounds per acre lime (L) or pounds per acre sulfur (S) needed to bring soil reaction into the appropriate range, cation exchange capacity (CEC) is expressed as either OK or LOW. Adjustment of N or CEC can be done with organic matter additions as noted earlier in this presentation or in the cover letter. So, according to the first two lines of data in the third section of soils: soil sample A-2North from Fort Collins, Colorado State Nursery shows that the soil could use supplemental nitrogen and that the pH is a bit high and could use adjustment prior to the next conifer crop. If hardwoods-shrubs should be sown in this portion of the Fort Collins nursery, additional phosphorus and magnesium are recommended and pH adjustment may not be required.

Section 4 contains seedling morphological data. The heading at the top of the sheet reads:
NY S 1978 NS 2-0 LOCATION 6-A(6) NORTH SEEDLING/ SQ

FT 27

This heading identified a seedling sample from the Saratoga New York State Nursery, sampled in the autumn of 1978, of 2-0 Norway spruce from area 6-A(6) North, at a density of 27 seedlings per sq. ft. All the information between this heading and the next pertains to this sample: mean foliage, stem, top, root and total seedling dry weights in grams, and percentage of each component of the total seedling weight, and mean top/root ratio. Also, mean stem diameter at root collar, total height, and height growth in millimeters in year sampled along with their standard deviations (SD) and coefficients of variation (CV). Also, given is the mean height/diameter quotient and the seedling quality index.

Section 5 contains seedling chemical analysis data. The heading at the top of the sheet is the same as the sample described above. Each printout page contains all the chemical analysis information on one seedling sample: sample description and density, mean seedling components (COMP) divided into foliage (F), stem (S) and roots (R), showing dry weight in grams per component, then percent (PC) or parts per million (PPM) concentration of N, P, K, Ca, Mg, Mn, Na, Fe, Zn, Al, Cu, and ash by components, then weight in milligrams (MG) per mean seedling (SDLG) of the same elements (obtained by multiplying concentration values by mean dry weight values) by components, then the milligram weight per square foot (SQ FT) of seedbed of the same elements (obtained by multiplying element weight per mean seedling by seedbed density) and finally the distribution of the element contents by components under percent of total (PC TOTAL), i.e. 50% of the total N may be in the foliage, 25% of the total N may be in the stems, and 25% of the total N may be in the roots. These analyses data give an estimate of the amount of elements retained in the seedlings and the amount of elements that will be removed from the site at harvest. We plan to use these content values, a measure of nutrient drain from the site by seedling harvest, to enable us to improve our future fertilizer recommendations.

By the way, note on the computer printouts, sections 4 and 5, the effects of composted horse manure on Norway spruce. Sample 6-A(6) North is from the manure treated area while sample 6-B(2) South is from the non-manure treated control area. The composted manure has had a marked positive effect on the Norway spruce seedlings.

Please note on the order form for participating nurseries in our service that sampling is on a Spring/Autumn basis now for soil samples to suit the various schedules of nurseries. Spring soil samples should be in the Syracuse lab as early as possible but no later than June 1 in order that the data and interpretations may be returned to the nurseries by September 1 - about a 3-month turn around time. Summer-Autumn soil samples should be in the lab again as early as possible but no later than November 1 in order that the data and interpretations may be returned to the nurseries by February 1 - about a 3-month turn around time. Plant samples need to be taken in early autumn and have a longer turn around time than do the soil samples.

Soil and seedling sampling guides are in the handout packet, and should be followed as closely as possible to insure validity of data from these samples.

Finally, it should be clear that the nurseryman is and must be the best judge of how his soil management program should be conducted. Soil and plant analyses data and interpretations as provided by our service are meant to aid the nurseryman in his soil management program. We believe the service is useful, and we will continue to improve it as best we can.